

The Behavioral Reactions of a Snake and a Turtle to Abrupt Decreases in Gravity

RICHARD WASSERSUG¹ and AKEMI IZUMI-KUROTANI²

¹*Department of Anatomy and Neurobiology, Faculty of Medicine, Sir Charles Tupper Medical Building, Dalhousie University, Halifax, Nova Scotia, B3H 4H7, Canada, and* ²*Space Utilization Research Center, Institute of Space and Astronautical Science, 3-1-1, Yoshino-dai Sagamihara, Kanagawa 229, Japan*

ABSTRACT—We report here on the behavioral reaction of two reptiles to abrupt decreases in gravity. One striped rat snake, *Elaphe quadrivirgata*, and three striped-neck pond turtles, *Mauremys japonica*, were exposed to microgravity (μ -G) on parabolic flight, during the filming of a documentary for the NHK television station in Japan. The video films revealed that the snake reflexively responded to the shift from hyper- to hypogravity by taking up a defensive posture—on the first parabola, the snake struck at itself. The turtles actively extended their limbs and hyper-extended their neck in μ -G, a posture which is identical to that displayed during their contact “righting reflex”, when placed upside-down in normal gravity. The aggressive display of the snake was unexpected, although the righting response of the turtles was consistent with that shown by other vertebrates, including fish and mammals, exposed to μ -G. An implication of these observations is that the afferent signal for the righting reflex of vertebrates in normal gravity must be the unloading of ventral receptors in the sensory system, rather than the loading of dorsal receptors. These are the first behavioral records for any reptiles exposed to hypogravity.

INTRODUCTION

In the nearly half century that man has been exploring space, a plethora of organisms have been exposed to microgravity (μ -G) either briefly, on parabolic flights, or for longer periods, on orbital missions. Several birds, reptiles, amphibians and fishes, as well as a large variety of mammals have all been exposed to μ -G [2]. Most of this work has focused on the physiological consequences of reduced gravity. Surprisingly little attention has been given to the reflexive behaviors of these organisms upon their initial exposure to microgravity. It is not known, for example, whether there are consistent patterns in the reflexive responses of animals to abrupt changes from hyper- to hypo-G. Do the responses of various vertebrates correlate with their phylogenetic relationships or way of life? Can we predict how any

animal will react, for example, in freefall?

Early work with teleost fishes [e.g. 5, 6] suggests that aquatic vertebrates reflexively pitch downward in μ -G and that this leads to looping (forward somersaults). More recent studies, however, with a larger variety of aquatic species (Wassersug, unpublished data) suggest that such forward looping is not characteristic of all lower vertebrates exposed to μ -G. Some amphibian larvae, for example, make forward somersaults (e.g. *Xenopus*), whereas others make backward somersaults (e.g. *Bufo*). Others (e.g. *Rana*) float freely and still others twist and roll along their long axis while swimming forward in short dashes [3, 7, 9, 10]. Clearly, more animals will have to be examined before systematic patterns in the behavioral responses of vertebrates to decreased gravity can be revealed. Ultimately, if behavioral research in gravitation biology is to become a predictive science, such patterns should exist and be identifiable.

As a step towards producing a broader data base on the behavioral responses of vertebrates to de-

creased gravity, we report here on the behavior of a snake and three turtles exposed to changing gravity in parabolic flight. The behavior was videotaped in the early spring of 1992 by the Japanese television station NHK, in preparation for their April 6th, 1992 television program "Kura-bete Mireba" (Comparative Ethology for the General Public). Although the film sequences discussed here were not used in the final production of the documentary, they were graciously made available to us for study.

To the best of our knowledge, there are no other records of the behavior of reptiles in parabolic flight. The great morphological difference between a snake and a turtle and their dramatically different responses, as noted below, emphasize how different the responses of organisms to decreased gravity can be.

MATERIALS AND METHODS

The snake used in this experiment was a single specimen of the common striped rat snake of Japan, *Elaphe quadrivirgata*. This an active, semi-arboreal snake. The turtles used were specimens of the Japanese striped-neck pond turtle *Mauremys [Clemmys] japonica*. All specimens were on loan to NHK from a local pet store in Nagoya, Japan, and were returned to that store at the end of the mission. Species identifications were confirmed by the supplier, but regrettably no other information on the specimens was recorded. Judging from the size of the containers holding the animals during the flight, we estimated that the snake was 75 cm long. The carapace lengths for the three turtles were similarly estimated at 6–8 cm, 10–12 cm and 13–15 cm respectively. All animals were active and in clearly good health.

The behavior of an additional turtle of the same species and size of the largest turtles exposed to μ -G was examined in the laboratory at the Biology Department of Shimane University, Matsue, Japan.

The snake was flown alone; the three turtles were flown together. For flight the animals were housed in a simple, smooth-sided aquarium without water. The maximum and minimum dimensions of their containers were on the order of half a

meter to a third of a meter respectively. The aquarium was braced in the pressurized, temperature-controlled cabin of a Mitsubishi MU 300 aircraft. A fix-mounted Sony Hi 8 video camera continuously filmed the animals throughout their parabolic flights. The snake and turtles were each exposed to eight parabolas. The parabolic maneuvers were performed between 6.6 and 8.5 km elevation and provided in excess of 15–18 sec of μ -G (i.e. $G < 10^{-3}$), with intervening hyper-G episodes of approximately 2-G.

RESULTS

Snake

Before the first parabola, the snake was actively exploring its cage. The animal had climbed the vertical edge with the front half of its body and was probing an upper corner with its head, as if searching for a crack or crevice to enter. As the aircraft entered μ -G on the first parabola, the snake immediately retracted its head into three tight curves. The animal thrashed about violently, twisting and rolling. Three seconds into μ -G, a mid-portion of the snake's body came within approximately 10 cm of its head. At that moment the snake struck at itself (Fig. 1). As soon as the head hit the body, it was withdrawn. The action was so fast that we could not confirm from the video images (only alternate ones of which are shown in Fig. 1) whether the mouth was open during this snout-body contact or whether teeth were planted in the skin.

For the remainder of the parabola the snake's head stayed cocked, as if prepared to strike again. At the initiation of reduced gravity on each subsequent parabola, the snake immediately cocked its head into the pre-strike posture just described. Additional strikes, however, were not observed. On the 3rd, 4th and 6th parabolas, the animal successfully braced a portion of its body between the top and bottom of its aquarium and stayed in contact with the container throughout μ -G. This bracing eliminated most of the chaotic twisting and rolling seen in the earlier parabolas.

The snake's response to the hyper-G phase of the parabolic trajectory before its first and subse-

quent exposure to μ -G was, in contrast, subdued. Whenever G increased from <1 to >1 the snake was, understandably, forced toward the bottom of its container. When the animal had a portion of its

body elevated during hyper-G, it could be seen straining to maintain its posture. However, at no time in hyper-G did it respond either hyperactively or aggressively, as it did during the shift from hyper-G to hypo-G on the first parabola.

Turtles

The reaction of the turtles to reduced G, in contrast to that of the snake's, was slower and more subdued. At the onset of μ -G, the turtles either stayed in contact with a substrate or were thrown between surfaces due to fluctuation in their acceleration relative to that of the aircraft. The turtles had no control over their trajectory in μ -G and tumbled until they hit a wall or one another. They did not withdraw into their shells. On the contrary, they extended their necks and raised their heads while at the same time fully extending and elevating their limbs (Fig. 2). The digits, most notably on the hind limbs, were spread while the foot was rotated along the long axis of the limb,

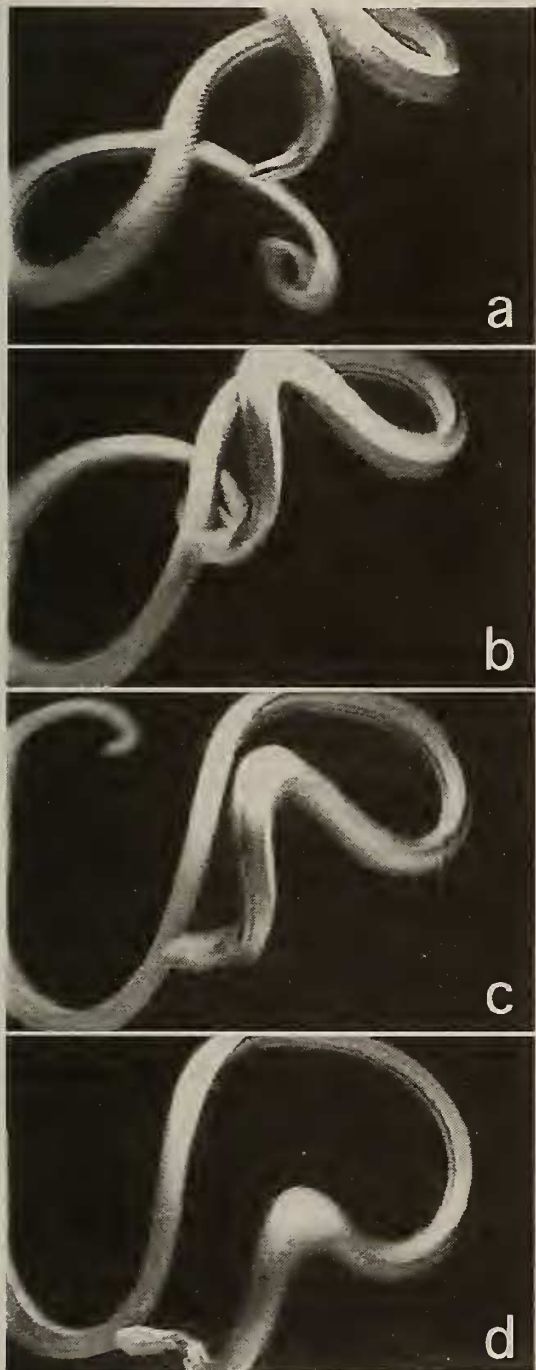


FIG. 2. A video image of a pond turtle, *Mauremys japonica*, in microgravity. Note the hyper-extension of the neck and the asymmetric dorsal deviation of the extended limbs. The same hyper-extension of head and limbs is used by *M. japonica* in normal gravity to generate torque through its long axis and thus to right itself when upside-down by rolling over. The video image has been computer enhanced as in Fig. 1.

FIG. 1. Four sequential video frames of the rat snake, *Elaphe quadrivirgata*, in microgravity. In the first frame (a) the snake's head is in the middle of the field. In the subsequent two frames (b, c), the snake's snout strikes its body then descends to the bottom left of the field (d). The frames are separated by 20 msec. The video images have been computer enhanced to remove extraneous reflections from the container's walls.

bringing the anterior, leading edge upward. The impression created was one of the animal trying to reach or contact, with its head and limbs, objects dorsal to it. The limbs on both sides were not extended or elevated equally; that is, the maneuver was not performed symmetrically.

The dorsal extension just described was exhibited by a turtle during normal gravity in the aircraft when it "landed" upside-down. The posture was used by the turtle specifically to right itself. It was completely duplicated by *M. japonica* in the laboratory at Shimane University by simply putting the turtle upside-down on a styrofoam sheet. In that position, the turtle was able to contact the surface with its extended snout and claws and hold itself in place, such that it could quickly flip over, i.e. "roll" in aviation parlance. On the smooth surface of the flight container, the maneuver was futile except in one case involving the smallest turtle.

The turtles showed little response to either the initial or subsequent episodes of hyper-G. If they were free floating when G shifted from <1 to >1 , they were propelled toward the bottom of their aquarium. They did not, however, retreat into their shells or exhibit other signs of undue stress in hyper-G. No progressive changes in the behavior of the turtles were seen as they went through the multiple parabolas.

DISCUSSION

The behavior of reptiles in decreasing G can be readily understood as a manifestation of behaviors that they show in 1-G under special circumstances. There is nothing in their behavioral repertoire during parabolic flight that can be said to be either G or "space specific." The behavior that the snake exhibited was, however, quite different from that of the turtle.

The cocked neck and strike shown by *E. quadrivirgata* as G decreased was clearly of a defensive sort. The writhing and twisting, particularly in early parabolas, is indistinguishable from that of the normal frightened and threatened *E. quadrivirgata*. The fact that the snake actually struck at itself suggests that the animal suffered loss of proprioceptive clues about body position in μ -G.

On the other hand, *Elaphe* snakes are naturally preyed upon by hawks in Japan and they occasionally experience aerial suspension when captured. In this situation, it is in the snake's best interest to strike, even to strike blindly! Such a response may have been demonstrated by *E. quadrivirgata* during the shift from hyper- to hypog-G.

Snakes vary greatly in their response to tilting in 1-G, depending on whether they are terrestrial or arboreal [4]. In this regard, it would be particularly interesting to see whether other snakes that are more or less arboreal than *Elaphe* show the same defensive response in μ -G and parabolic flight.

The turtles responded to μ -G as if they were upside-down [1]. This has implications to understanding the stimulus for their righting reflex in 1-G. Specifically, the afferent signal for the hyper-extension of the neck and limbs used in the righting maneuver cannot be the *loading* of dorsal sensory receptors. Rather it must be *unloading* of ventral receptors.

Hyper-extension of the axial skeleton with asymmetrical limb movements has been observed in other vertebrates in μ -G. The combined limb and axial movements lead to long-axis rotation, or rolling. In 1-G this appears to be an important part of a righting reflex best known in arboreal and semi-arboreal vertebrates, such as the cat. The same maneuver is seen, however, in a variety of less arboreal animals in μ -G. These range from aquatic animals, such as the adult clawed frog (*Xenopus*) and salamander larvae [3, 8], to strictly terrestrial mammals, such as the rabbit (on the NHK video film, unpublished data). What distinguishes these behaviors in μ -G from the 1-G situation is that they are more repetitive and protracted in freefall, simply because they are not effective. The ability to duplicate these displays in turtles and many other animals by simply inverting them supports the conclusion that they are manifestations of a natural righting reflex.

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